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TEMPERATURE IDENTIFICATION OF DRILLING PROCESS USING THERMOVISION METHODS

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ABSTRACT
The paper presents an attempt to temperature measurement in the cutting zone of drilling using a thermovision method and a heat model of driller using the finite elements method simultaneously. During the research the attention was focused on method, which directly does not interfere the cutting process. The main criterion of the analysis was the possibility of the utilization of the method in temperature monitoring system of the drilling process.
It means that identification of temperature requires association of measured signal and model based on calculation. The temperature of non-cutting part of driller is measured directly using a pyrometer and results of such measurement are loading to the FEM model. At present it is done off-line but in the future it should be done on-line. This method enables to identify temperature in such places where direct measurement is impossible.
Keywords: monitoring of drilling, cutting process, thermovision, emissivity coefficient

1. INTRODUCTION
The temperature measurement while the drilling is very difficult because of no direct access into cutting zone. This article focuses on the methods measuring the cutting temperature in the cutting zone on the basis of tool temperature measuring. One of the best of the temperature measuring method in the point of view of diagnostic is continuous measuring depending on the cutting temperature.
A general assumptions of monitoring methods of a tool temperature relies on question: to use a tool or a workpiece or a chip as a heat sensor, so as to do not interfere in the cutting process, when access to cutting zone is difficult (i.e. drilling process). The measurements method, which determine a body temperature on the basis of his energy state requires precise identification of a body properties concerning a capable of radiation emission. Temperature radiation, which is emitted by separate components of the cutting process, will give information about temperature of components if the body properties are determined. Some problems associated with them and the way of solution them is described in article [1], whereas in regarding to components of the drilling process in article [2].

2. RADIATION TECHNIQUE USING TEMPERATURE MEASUREMENT DURING THE CUTTING PROCESS
The first use of this technique was reported by Schwerd [3] who developed a total radiation pyrometer for determining the temperature distribution at the surfaces of the tool and workpiece during determination the orthogonal cutting [Fig.1a]. The technique was further developed by Kraemer [4]. Several workers attempted to overcome the problem of access to the chip-tool interface by scanning through holes drilled either in the workpiece or tool. Reichenbach [5] determined the temperature in the shear plane using a PbS cell, the radiation being directed through a hole in the workpiece. The temperature distribution on the flank face of a cutting tool was measured by Chao [6] using a PbS cell

and Bornhoefer and Pahilitzsch [11] using a geranium photodiode. The temperature distribution at chip-tool interface has been measured by Lenz [8] by scanning through the tool and Van Woerden [9] and Prins [10] who scanned the interface through the chip. Boothroyd [11] used a microdensitometer for measuring the point-to-point intensity of radiation with the aid of a suitable negative calibration. When dispensing with the use of coolants in while metal removal operations, the increased friction involved and the simultaneous lack of heat dissipation will result in an increased temperature load on the tool. Specifically in drilling, as a process with concealed cutting edge, friction between the land and the borehole wall also become effective apart from chip surface friction. In addition to this, the tool heats up during disposal of the hot chips from the bottom of the borehole. Dorr [12] using a technique of the 'in-situ' measurement during a dry drilling operation (Fig. 1b).

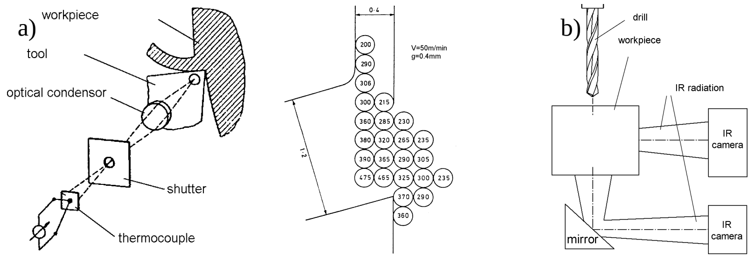

Figure 1. a) Temperature distribution at shear plane obtained by Schwerd [3].
b) Scheme of the test installation using by Dorr [12].

The maximum tool temperature occurs at the maximum borehole depth and is, therefore, measured at that point. If the thickness of the test workpiece is adapted to the desired borehole depth, measurement will have to be done at the time when the bit of the drill passes through the workpiece bottom. Prior to this also, the progressive heat-up of the workpiece can be recorded. For recording the temperature of the tool and the workpiece, the heat radiation emitted is determined by contact-free means via the thermographic camera system. Beneath the workpiece, the 45° deviation mirror is arranged in a guide system permitting height adjustment.

3. TEMPERATURE MONITORING SYSTEM CONCEPTION

The global assumption of monitoring the temperature of cutting tool using a non-contactable method in the case of very difficult accessible of cutting zone (for example while drilling) amount to make use of modules of cutting process like cutting tool or workpiece as source of heat. The heat is the main reason of temperature distribution in the cutting zone.

The temperature identification in the cutting zone takes place off-line using a mathematical model (Finite Element Method model) and using data obtained from pyrometric measurement of temperature not in the cutting zone but in the part of cutting tool zone situated beyond cutting zone. In our conception of temperature measurement we used the FEM model of distribution of heat generated while cutting process. Figure 2 presents the idea of our temperature monitoring system of cutting process while the drilling explaining connection between all modules of such system.

We have to underline that in our conception of temperature identification of using pyrometric sensor measurement may be realized as one-point measurement or 2 dimensional (2D) measurement.

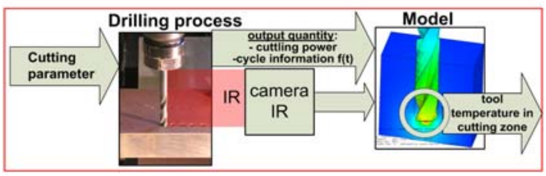

Figure 2. Conception of temperature system monitoring while drilling.

4. PRELIMINARY RESEARCH

The investigations were conducted using IR camera with spectral range 8-14 μm and image resolution of 320x240 pixels. The experimental researches were conducted using different cutting parameters and drillers diameters. The type of drillers was DIN338. The numerically controlled milling machine was used during the experimental research. During the research using the steel St3 workpiece (sheet gauge - 20mm) was used. The idea of temperature measurements applying thermovision camera relies on using the radiation reflector IR to measure tool temperature of the end of drill while the reboring drilled workpiece. That solution permits to realize the measurement from two points of view in the same time using one pyrometer equipment (Fig. 3).

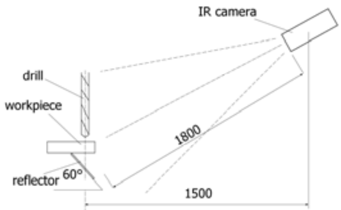

Figure 3. The temperature measuring stand.

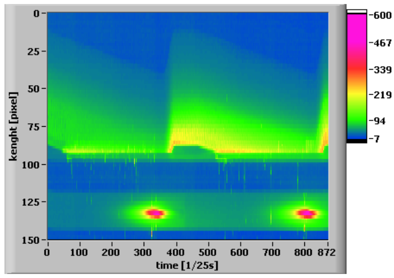

Figure 4. View in IR range of linear temperature distribution of driller axis with respect to time.

The acquisition and analysing of thermographic data was realized by using the NI LabView software. The velocity of canvassing was equal to 25 frame per second. On the basis of tool producer catalog data [13] and preliminary test of cutting, parameters were determined. The research was performed for the followings parameters: cutting speed: υ_c=10 and 23m/min and feed rate number 3 and 5. In article [2], was presented the stab and software system where problem of emissivity during the temperature pyrometric measurements was described. The additionally research were conducted where emissivity coefficient values for separates components of the cutting process and used reflector IR stand were determined.

During the analysis of temperatures matrix, on the basis of pyrometric properties separate considered visible surface on photo-picture in the range of visible radiation can determine emissivity coefficients (ε) treating them as homogenous. The theoretical bases were showed in articles [2], where were recalculated the temperature at ε=1 for real temperature i.e. corrected temperature at real emissivity coefficient for measured surface. During the research, the camera was focused on the workpiece. The analysis of thermographic image were performed in LabView software as is shown on Figure 4.

The techniques development in the field of temperature measurements by the non-contact methods, which uses energy of heat radiation, suggests the possibility of application those methods to identification of temperatures field in the cutting process. Presented results are only examples of application of termovision devices for the measurements of temperature field during the drilling process. In the future its can be used as effective system to monitor of temperature during the drilling process.

5. IDENTIFICATION OF THERMAL MODEL OF DRILLER

The temperature of non-cutting part of driller is measured directly using a IR methods and results of such measurement are loading to the FEM model. At present it is done off-line but in the future it should be done on-line. This method enables to identify temperature in such places where direct measurement is impossible, for example in the cutting zone of drilling holes.

Time performance of temperature in several characteristic points of cutting tool situated in the center of its axis are show on Figure 5.

Distribution of corrected temperature was modified moving the part of temperature performance of reflector so that the maximum temperature of the peak point of driller was situated in real position. Using such modified visualization of temperature distribution along driller's axis was added the results obtained from experimental research (FEM on Figure 6).

The identification of temperature in cutting zone using simulation method (Finite Element Method) gives results similar to results obtained from experimental research using the pyrometric method of temperature measurement. Disturbances while temperature performance obtained from experimental research are caused by chips created while the drilling. The character of the disturbances generally don’t cause difficulties in interpretation obtained results.

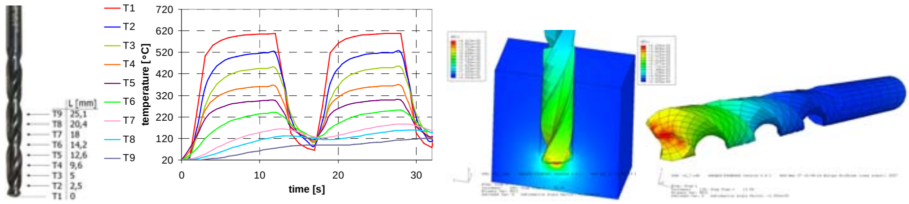

Figure 5. Time performance of temperature obtained from simulation research in several characteristic points of cutting tool situated in the center of its axis for different length L of driller point and example of temperature distribution obtained from heat simulation.

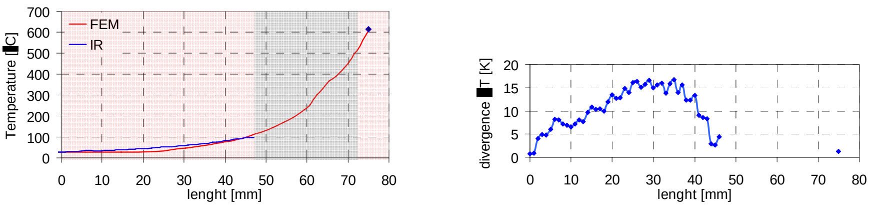

Figure 6. Temperature distribution of driller along its axis obtained from simulation MES and experimental research while drilling holes (v_c=28,3 m/min and f=0,06 mm/rev.) and error of temperature absolute value of the difference of temperature from FEM and experimental research.

6. CONCLUSION

The techniques development in the field of temperature measurements by the non-contact methods, which uses energy of heat radiation, suggests the possibility of application those methods to identification of temperatures field in the cutting process. Presented results are only examples of application of thermovision devices for the measurements of temperature field during the drilling process. In the future its can be used as effective system to monitor of temperature during the drilling process.

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